FACIAL EXPRESSIONS EMOTIONAL RECOGNITION WITH NAO ROBOT

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ABSTRACT

Human-robot interaction research is diverse and covers a wide range of topics. All aspects of human factors and robotics are within the purview of HRI research so far as they provide insight into how to improve our understanding in developing effective tools, protocols, and systems to enhance HRI. For example, a significant research effort is being devoted to designing human-robot interface that makes it easier for the people to interact with robots. HRI is an extremely active research field where new and important work is being published at a fast pace.

It is crucial for humanoid robots to understand the emotions of people for efficient human robot interaction. Initially, the robot detects human face by Viola-Jones technique. Later, facial distance measurements are accumulated by geometric based facial distance measurement method. Then facial action coding system is used to detect movements of measured facial points. Finally, measured facial movements are evaluated to get instant emotional properties of human face in this research; it has been specifically applied to NAO humanoid robot.

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"I hereby declare that the work in this project report is my own except for quotations and summaries which have been duly acknowledged."

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CHAPTER 1

INTRODUCTION

1.1 Project background

The most well-known method to detect and recognize human basic emotion and communication with robot is to extract some features of human speech, voice, and through facial expressions especially. According to many scientific papers have been demonstrated that when people have communicated with each other, facial expressions have been included 55% of the massage meaning, vocal and verbal cues provide 38% and 7% respectively[1]. Thus, several research studies have been performed recently to achieve more reliability and robustness of human emotion recognition method.

To interact easier with robots, people put forward new demands to human robot interaction[2][3]. Hopefully, robots can recognize human's facial expressions in addition to understanding emotions and give suitable response. In recent years, emotional intelligence of robots has obvious attention from lot supporters all over the world. Emotional robot research have covered many fields such as psychology and computer science [4][5]. Mascot Robot System including 5 eye robots was proposed in[6][7], in which the robots can demonstrates friendly interaction to human. A face robot “KAPPA” which is proposed in[8] can detect and recognize facial expressions and generate 6 basic emotions such as happiness, fear , sadness, anger, disgust and surprise. Smart robot called Minotaurus which is proposed in [9] that consider advanced robot can interact with human by using speech, facial expressions and gestures. Although a lot of researchers have treated the emotion of robot, a few researches have been done to study emotion recognition and emotion expression to perform a suitable and smooth communication with robot[10].

A facial expression emotion recognition based human robot interaction system is introduced which is related to multi-model emotion communication based on human robot interaction system [11][12]. Our system is designed firstly to achieve three targets: one is detecting human face. Secondly, demonstrating the ability of robot to detect properly human facial emotional expressions, thirdly, robot ability to generate suitable expression adapting with human facial expressions.

The processes of operation system consist of 3 steps. Firstly, camera of NAO robot collects human face image to analyze and do processing. Viola Jones method is applied to detect human face, then Geometric based facial distance measurement method and facial action coding system are applied. Finally, NAO robot generates suitable interaction according to facial emotional expressions[13].

1.2 Problem statement

Robots are widely becoming an important part of our daily life. It is crucial for humanoid robots to understand the facial expressions of people for generating efficient human-robot interaction. Although some researchers have treated the facial expressions using robots such as Mascot, KAPPA and Minotaurus, a few researches have been done to study emotion expression to perform a suitable and smooth communication with NAO robot. But still there are some difficulties related to speed, accuracy and reliability approaching accurate algorithm to detect human face and another algorithm to differentiate facial emotional expression to get rid of some of these obstacles to make using robots more effective in our life.

1.3 Aims and objectives

The aim of this project is to develop human robot interaction algorithm with NAO robot facial expression.

The objectives as following:

1. To develop human face recognition algorithm.
2. To differentiate facial emotion expressions.
3. To develop human robot interaction based on human facial emotional recognition.

1.4 Scope

NAO robot has a great capacity to sense his environment as image processing on the work on the robot CPU; we can use up to 30 images/second in HD resolution. NAO can move the head by 239° horizontally and by 68° vertically and his camera can see at 61° horizontally and 47° vertically. For the development of the HRI algorithm, the NAO Robot Version 4 by Aldebaran is used (Aldebaran, 2015)[14]. Figure 1-1 shows the robot capabilities which are:

- Prehensile hands that can mimic the movement of a human hand.
- Walking movement to navigate from one point to another based on visual processing
- Audio recognition to make decisions and perform related actions
- Tactile sensors that acquire data from physical contact with the environment.
- Visual recognition to identify correct objectives[15].

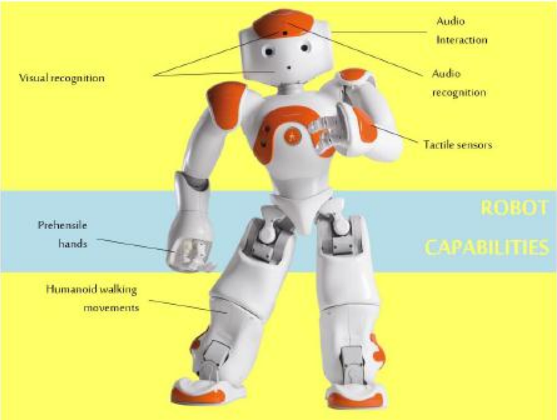

Figure 1.1: NAO robot capabilities (Aldebaran, 2015)[16].

The programming platform is Choregraphe Robot Software version 2.1.3 dedicated to monitor and control robot movement. The HRI algorithm is a system that enables to recognize firstly human face then differentiate facial emotional expressions such as happiness, sadness and surprise. In addition, it is able to generate suitable human robot interaction based on human facial emotional recognition.

CHAPTER 2

LITERATURE REVIEW

2.1 Human robot interaction (HRI)

Human Robot Interaction has recently received considerable attention in the academic community, in government labs, in companies of technology and through all the media[17]. HRI is a field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans. Interaction, by definition, requires communication between robots and humans. Interconnection between a robot and a human take different types, but these forms are highly affected by whether the human and the robot are in close proximity to each other or not. So we have two different categories as following:

Firstly remote interaction which the robot and human are not located and separated both in space and time. Secondly close interaction which robot and human are co-located such as service robots may be in the same room as humans.

Within these two general categories, it is useful to distinguish between applications that mobility, physical manipulation, or social interaction. Remote interaction with mobile robots is often related to as teleoperation or supervisory control, and remote interaction with a physical manipulator is related to as telemanipulation. Proximate or close interaction with mobile robots may take form of robot assistant, and close interaction may include a physical interaction. Social interaction is often related to social, emotive, and cognitive aspects of interaction. In social interaction, robots and humans interact as peers or companions. Importantly, social interactions with robots appear to be proximate rather than remote[12].

The HRI problem is to understand and shape the interaction between humans and robots. Interactions between robots and humans are inherently present in all or robotics, even for so called autonomous robots. As a result, evaluating the capabilities of robots and humans, and designing the technologies and training which produce target interactions are important components of human robot interaction. Such work is inherently interdisciplinary in nature, including cognitive science, psychology and linguistics, form computer science, mathematics and engineering; also form human factors engineering and design.

Although anticipated and existing interaction analysis patterns is important, it is helpful to adopt the designer's perspective by breaking HRI problem into its constituent parts. In essence, a designer should consider five factors that affect the interaction process between robots and humans:

- Nature of information exchange,
- Level and behavior of autonomy,
- shape of task.
- Adaptation, learning, and training of people and the robot,
- Structure of the team,

Interaction, the process of working together to accomplish a goal, emerges from the confluence of these factors. The designers try to shape and understand the interaction itself, with the objective of making the exchange between robots and humans beneficial in some sense. Similar taxonomies are certainly possible, identifying how people perceive a robot's role has essential ramifications for how they interact with the robot[12]. Using Scholtz's taxonomy provides insight into the current and future interactions in these applications. Table 2-1 shows the most recent types of interactions for the application areas.

Table 2.1 shows examples of roles and proximity patterns for different applications area[12].

Application area	Remote or proximate	Role	Example
Search and rescue	Remote	Human is supervisor or operator	Remotely operated search robots.
	proximate	Human and robot are peers.	Robot support unstable structure
Assistive robotics	proximate	Human and robot are peers, or robot is tool.	Assistance for the blind and therapy for the elders.
	proximate	Robot is mentor.	Social interaction for autistic children.
Military and police	remote	Human is supervisor	Reconnaissance, de-mining
	Remote or proximate	Human and robot are peers.	Patrol support
	remote	Human is information consumer.	Commander using Reconnaissance information.
Edutainment and psychology	proximate	Robot is mentor.	Robotic classroom assistant.
		Robot is mentor.	Robotic museum tour guide.
		Robot is peer.	Social companion
space	Remote	Human is supervisor or operator.	Remote science and exploration.
	proximate	Human and robot are peers.	Robotic astronaut assistant.

2.2 NAO Robot: an overview

NAO humanoid robot is an autonomous, programmable bipedal robot created by Aldebaran Robotics[14]. It is about 58-cm tall and has the ability to move, recognize, talk to human beings and even hear. NAO robot is a platform of Two-Legged standard League[18]with the following key components:

- Body with 25 degree of freedom whose key elements are electric motors and actuators.
- Sensor network: two cameras, four directional microphones, sonar rangefinder, two IR emitters and receivers, one inertial board, nine tactile sensors and eight pressure sensors.
- Intel ATOM 1.6 GHz CPU (located in the head) that runs a Linux kernel and supports Aldebaran’s proprietary middleware (NAOqi)
- Second CPU (located in the torso).
- 48.6 watt hour battery that provides NAO with 1.5 or more hours of autonomy, depending on usage.

Figure 2.1 : ALDEBARAN NAO Robot Version 4.0 Logo by Aldebaran (2015)[16].

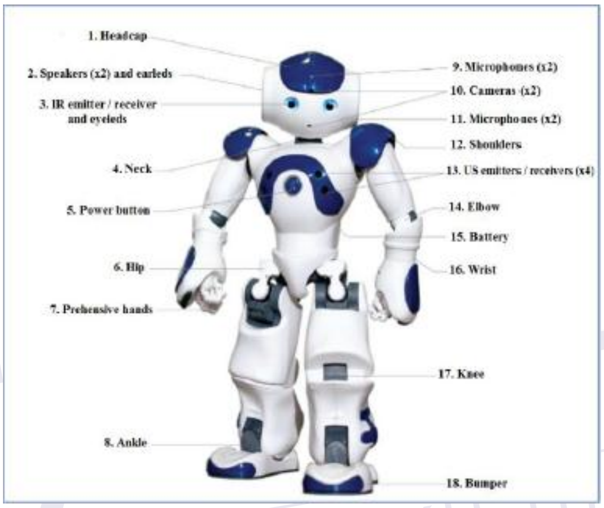

Figure 2.2: NAO robot[16].

NAO requires images through two identical video cameras located in the forehead and inside the mouth to detect the emotion suing facial expressions. Both of the cameras have resolution up to 1280 by 960 at frames per second. Each NAO cameras provides a vertical vision range of 47.64 degree as well as a horizontal vision range of 60.97 degree. Figure 16 shows the vision range of two cameras of NAO.

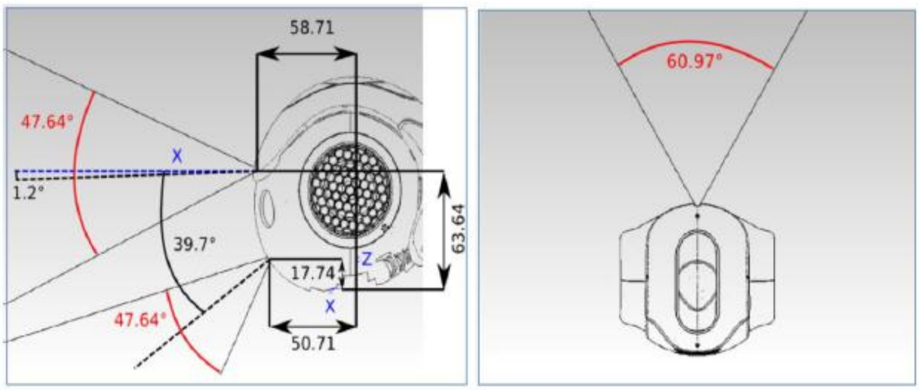

Figure 2.3: NAO robot vision vertical and horizontal Ranges[13].

Choregraphe software will be used to select cameras so, NAO can detect and understand the human face[19].

2.3 Face detection methods

In this project, some methods to detect face by using many algorithms are presented. Face detection is the first step to recognize human face, with the purpose of extracting and localizing the face region among many objects. There are many applications such as video conferencing, crowd surveillance and human robot interaction. The human face is considered as a dynamic target in addition to it has high level of variability in its appearance, which doesn't make detecting human face easy in computer vision. Many techniques are suggested from simple edge algorithm to complex high level approaches with pattern recognition techniques. Some of the recent face recognition methods suppose the availability of frontal faces[20][21]. It is necessary to mention that this suggestion may not hold because of the different nature of human face appearance and conditions of environment.

Figure 2.4 : Human face detection[22].

Human face could occur in complex background and in many different placements. Systems of recognition which are related to standard human face images are likely to mistake some regions of the background as a human face, so a visual front end processor is required to localize and get the human face from any general background. Detecting human face is one of visual processes which can be done to segment, extract and verify human faces and possibly features which are taken from uncontrolled background. Visual front end processor as a human face detection method should has the ability to perform the process, regardless of orientation, illumination and camera distance. Chellappa et al. had published a survey paper which discuss in detail face recognition research including segmentation and how to extract features from the image background[21].

Figure 2.5: Real face detection test[21].

The methods are categorized to algorithm related to features or algorithms related to image as shown in figure2-6. Many efforts in detecting face had been done in 1970 and onwards, where simple anthropometric and heuristic techniques were used[23]. These methods are widely rigid because of different assumptions such as frontal face, plain background—a typical passport photograph. Change of image features means fine tuning, if it is not a complete design. Although all these issues which had been faced, the research interest remained continuous until 1990[21], when video coding and face recognition systems had started to become a reality. Through the past decade, the research interest in face detection has been developed numerously; researchers have suggested robust segmentation algorithms, especially those using generalized information, color and motion. Also there are some techniques which use neural networks and statistics to detect faces from cluttered scenes from camera. In addition to numerous advanced researches in feature extractors design such as active contours and deformable templates which human face features can be located and tracked properly. Detecting face techniques requires facial priori information, so they can categories the techniques into two broad types specified by their different approach to utilize face knowledge. They methods in the first type make direct use of facial features and follow the classical detection method in which low level features are derived prior to knowledge based analysis[24][25]. Apparent features of the face such as face geometric measurements and the color of skin are exploited at different system levels. In these techniques face detection processes are accomplished by manipulating angles, area measurements and distance of visual properties which is accumulated from the general image background. Since features are the main ingredients, these methods are termed feature related approach. All these techniques have represented most of the interest in detecting human face research starting as early as the 1970s. Considering importance of the current advances in theory of pattern recognition. Image related approaches for face detection of example in 2D intensity arrays are categorized into a face group using training algorithms without features analysis and derivation[26]. Unlike the feature based methods, these relatively techniques incorporate face knowledge implicitly into the system through training methods and mapping.

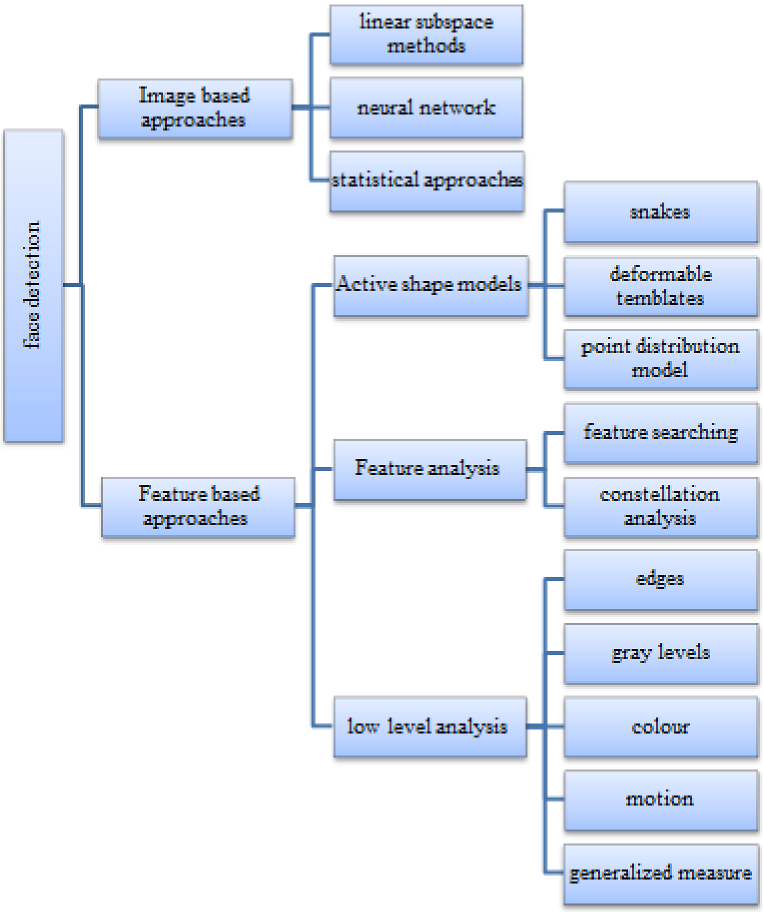

Figure 2.6 : Face detection divided into approaches[21].

2.3.1 Generalized Measure

Visual feature such as motion, color and edges are derived in the early stage of the human visual system shown by the various visual response patterns in our inner retina[27][28]. This process enables visual information to be ordered in different bases prior to high level visual activities in the brain. Depending on this note, Reisfeld et al.[29] suggested that the system of the machine vision must start with pre-monitor low level computation of features of generalized image. Reisfeld and Yeshurun[30]presented operator of generalized symmetry which is based on edge pixel process. Because of features of human face are symmetrical in nature, so if the operator that doesn't depend effectively on high level a priori knowledge of the human face, it produces a representation which delivers high response to facial property locations. The symmetry measure assigns a magnitude at every pixel location in an image depending on contribution of surrounding pixels. Magnitude can be determined as following:

$$M_{\sigma}\,(p) = \sum_{(i,j)\in\tau(p)} C(i,j), \qquad (2.1)$$

Where C(i,j) is contribution of the nearby pixel I and j (of pixel p) in the set of pixel. Both the set of pixel and the contribution can be described as following:

$$\tau(p) = \left[(i,j)\middle|\,\frac{Pi+Pj}{2} = P\right] \qquad (2.2)$$

$$C(i,j) = D_{\sigma}(i,j)P(i,j)r_i r_j, \qquad (2.3)$$

Where D(i,j) is a distance weight function, P(i,j) is considered as phase weight function, and Ri and r_j are determined as following:

$$D_{\sigma}(i,j) = \frac{1}{\sqrt{2\pi\sigma}}e^{-\frac{\|Pi-Pj\|}{2\sigma}} \qquad (2.4)$$

$$P(i,j) = (1-\cos(\theta_i+\theta_j-2\alpha_{ij}))(1-\cos(\theta_i-\theta_j)) \qquad (2.5)$$

$$r_k = \log\left(1+\left\|\nabla_{pk}\right\|\right) \qquad (2.6)$$

$$\theta_k = arctan\left[\frac{\frac{\partial}{\partial y}pk}{\frac{\partial}{\partial x}pk}\right], \qquad (2.7)$$

Where P_k is any point (X_k, Y_k) where k=1,……,K, ∇_{pk} is the gradient of the intensity at point P_k, and $\propto_{ij}$ is the counterclockwise angle between the line passing through P_i and P_j and the horizon[30]. Figure show the example of $M_{\sigma}(i,j)$ computed from the gradient of a frontal facial image. The symmetry magnitude map clearly demonstrates the facial features' locations features such as mouth and eyes[31].

Figure 2.7: Original image and M¾ of original image Reisfeld et al[32].

2.3.2 Neural network

This section proposes an algorithm to recognize faces in an image using a neural network approach Face recognition is a challenging problem which has received a lot of attention during the last few years due to its many applications in different fields such as surveillance law enforcement security applications or video indexing During the last few years various architectures and models of Artificial Neural Network (ANN) were designed for face detection and recognition ANN models can simulate the way neurons work in the human brain that is why ANN can be used in face detection and recognition The face recognition problem is perplexing as it needs to justify all possible appearance variation due to change in illumination facial features occlusions. This section gives a Neural and PCA based algorithm for effective and robust face recognition[33].

Pre-processing of faces is done to enhance the visual appearance of images and to improve the manipulation of datasets, the face recognition can be performed by using both PCA and Back Propagation Neural Network Multilayered neural networks can calculate a larger range of Boolean functions as compared to neural networks with a single layer Nevertheless the computational complexity for finding theright combination of weights increases considerably when more parameters and more complicated topologies are considered. The back propagation network can handle such complex learning problems.

Figure 2.8: Face recognition stages

The Algorithm for Face recognition using neural classifier is as follows:

- Pre-processing stage –Images are made unit-variance and zero-mean.
- Dimensionality Reduction stage PCA - Input data is reduced to a lower dimension to ease classification.
- Classification stage - The reduced vectors from PCA are used to train BPNN classifier to get the recognized image.

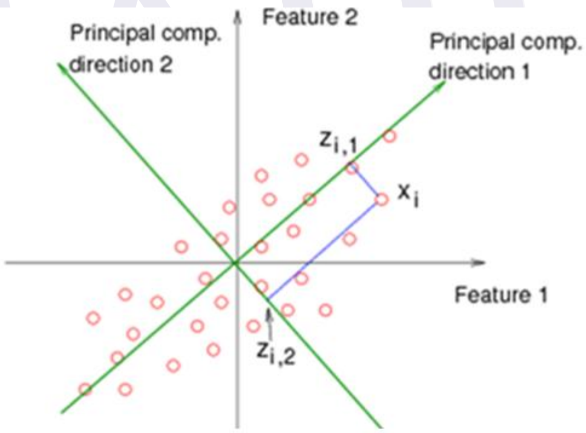

Figure 2.9: Principle component analysis[34].

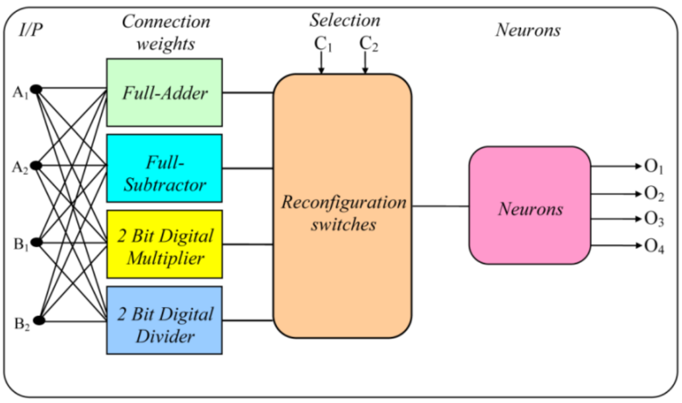

Figure 2.10: Block diagram of neural network[34].

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